Planning and Scheduling Software for Bed Rest Operations
Lessons Learned Toward a Crew Scheduling System for Exploration

Michael McCurdy[1], Jack Li[2], Melissa Ludowise[1]

[1]NASA Ames Research Center, MS 262-4, Moffett Field, CA 94035 / [2]San Jose State University Foundation, NASA Ames Research Center, MS 262-4, Moffett Field, CA 94035

Background

Future Constellation mission concepts will require a new suite of scheduling and planning tools that deliver improvements to current technology and processes, including:
- The ability to plan and reason about complex constraint networks on **long-range**, **mid-range**, and **tactical real-time** schedules
- The ability for human operators to effectively **manipulate and explain** schedules generated by automated planning software
- The ability for **the crew to assume the scheduling and planning roles** currently reserved for ground personnel

The Bed Rest Project

The Flight Analogs Bed Rest Project simulates the effects of microgravity by having volunteer subjects lie in bed with a head-down 6 degree tilt for 90 days as part of a 120-day campaign.
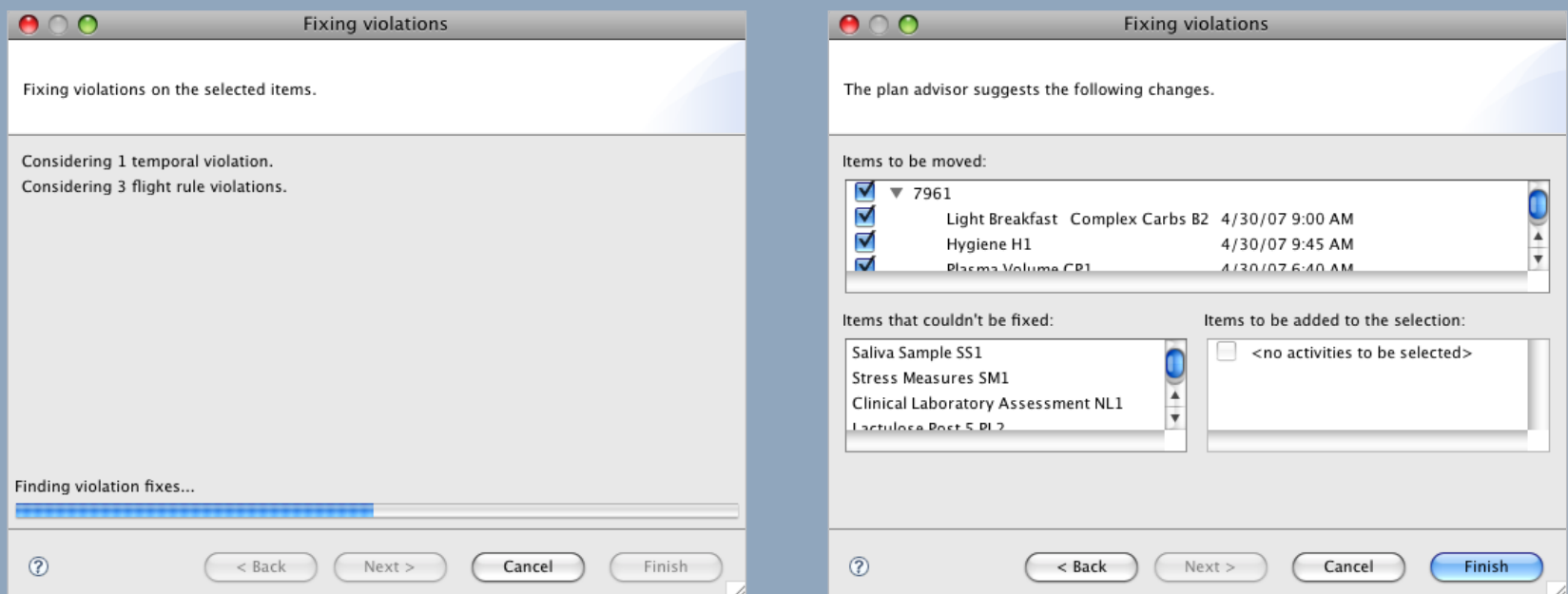
Approach

Drawing on **hundreds of hours of in-context observation** and experience developing tools[1] for the Mars Exploration Rover (MER) mission in 2003, the **Scheduling and Planning Interface for Exploration (SPIFe)** team began development in 2003 for the Mars robotic missions Phoenix and Mars Science Laboratory (MSL)[2]. A Bed Rest adaptation of SPIFe was implemented in 2007 with additional features to help the task of scheduling in a human domain. Although planning scheduling for robotic missions seems very different than scheduling in the human domain, it has many of the same core problems. We outline some our lessons learned in the Bed Rest domain here.

Automated Assistance Must Allow for Human Intervention

There are a number of commercial automated planners and schedulers that are designed to resolve any constraint violations in a plan or schedule, usually by moving or removing activities. *Most automated planners lack the ability to give the user enough control over what is being changed* in the plan and will:
- Sometimes take hours or days to solving all the violations in a schedule
- Often return an unreasonable schedule without any insight for its reasoning

SPIFe uses a **hybrid approach** of automated planning and user control by allowing the user to select a specific set of activities in the plan to resolve and by allowing them to accept or reject its proposed changes for each activity. The Plan Advisor will also always display all the violations that exist in a schedule and allowing the user to resolve them manually without the use of the automated planner.


Fixing Violations in SPIFe

The Schedule

The schedule represents the single agreed communication contract of how to operationally execute all the needs of the stakeholders in the Bed Rest project. Paper copies of the schedule are posted in all labs and rooms of the Bed Rest facility so that all nurses, subjects, and lab technicians are able to follow it without risk of violating any constraints.

It's the responsibility of a single scheduler to plan out the activities for each subject's daily schedule and take into account:
- The **tests** that are required on each Bed Rest day in the campaign
- The **daily activities** each subject must perform in addition to scientific tests (eg. Meals, Hygiene, Vitals)
- Any **operational or scientific constraints** involving the activities
- Personal requests

The scheduler will plan out activities two weeks in advance, send out the schedule on a weekly basis for approval from various stakeholders, and receive feedback for possible change requests. In addition, the scheduler must also change the schedule on short notice if an anomaly occurs when:
- **Equipment malfunctions**
- **A subject becomes ill** (and cannot perform certain tests)

In the event of an anomaly, the scheduler must alter the schedule, resolve any constraint conflicts and send the schedule out before the next morning.

Bed Rest schedule from previous operations

Bed Rest schedule report from SPIFe

Timeframe Model

The Importance of Constraints

There are numerous constraints on every activity in a Bed Rest schedule including:
- Operational Constraints
  - Room and equipment restrictions
  - Travel time that it takes to physically move the subject from floor to another for a test
- Scientific and Health Constraints
  - Drug or meal interactions that would interfere with data
  - Drug or meal interactions that could make a subject feel ill
- Personal Requests
  - Lab requests (eg. vacations, preference to not work on a weekend)
  - Subject requests (eg. eating meals at a certain time of the day)

In order to ensure all constraints are enforced in a schedule:
- The scheduler and all other stakeholders refer to a **written list of all constraints** when creating and verifying the schedule
- Validation that all constraints are being respected was accomplished only by **human checking**

Although many people reviewed the schedule repeatedly, the final schedule still sometimes contained **uncaught errors** which resulted anywhere from a subject getting nauseous to losing or missing the collection of data

Some statistics to illustrate how complex this task is:
- There are on average between **5 and 10 subjects in bed at a given time**, each of whom is in a different stage of a campaign
- Each subject has approximately **10 activities on any given day**
- There are currently **70 different Bed Rest activities** defined and a total of **222 constraints** and **21 operational notes** defined among them
- This can easily result in over 100 conflicts on one day in a schedule

To assist the scheduler with the task of enforcing all constraints in the schedule, SPIFe notifies the user of all existing violations in the plan in the **Plan Advisor**

Plan Advisor

Different Views for Different Tasks

SPIFe has two different ways of presenting the plan based on the user's task: the **Timeline** and the **Merge Editor** (a tabular view). The Timeline is what the Bed Rest scheduler primarily uses to edit the plan and displays activities in a chronologically in the horizontal direction and by subject in the vertical direction.
- Changing the time of an activity done by dragging the activity, represented by a rectangle, across the screen with the mouse.
- Information about the activity and timepoint of the mouse are displayed in the upper left corner.
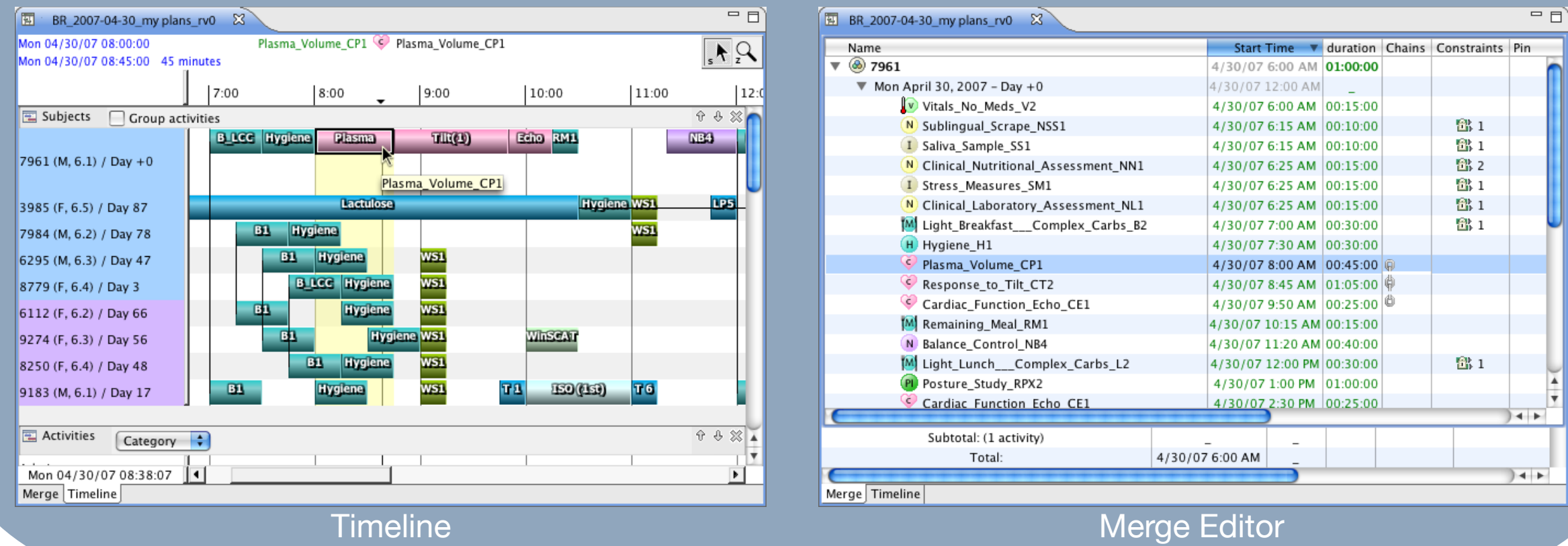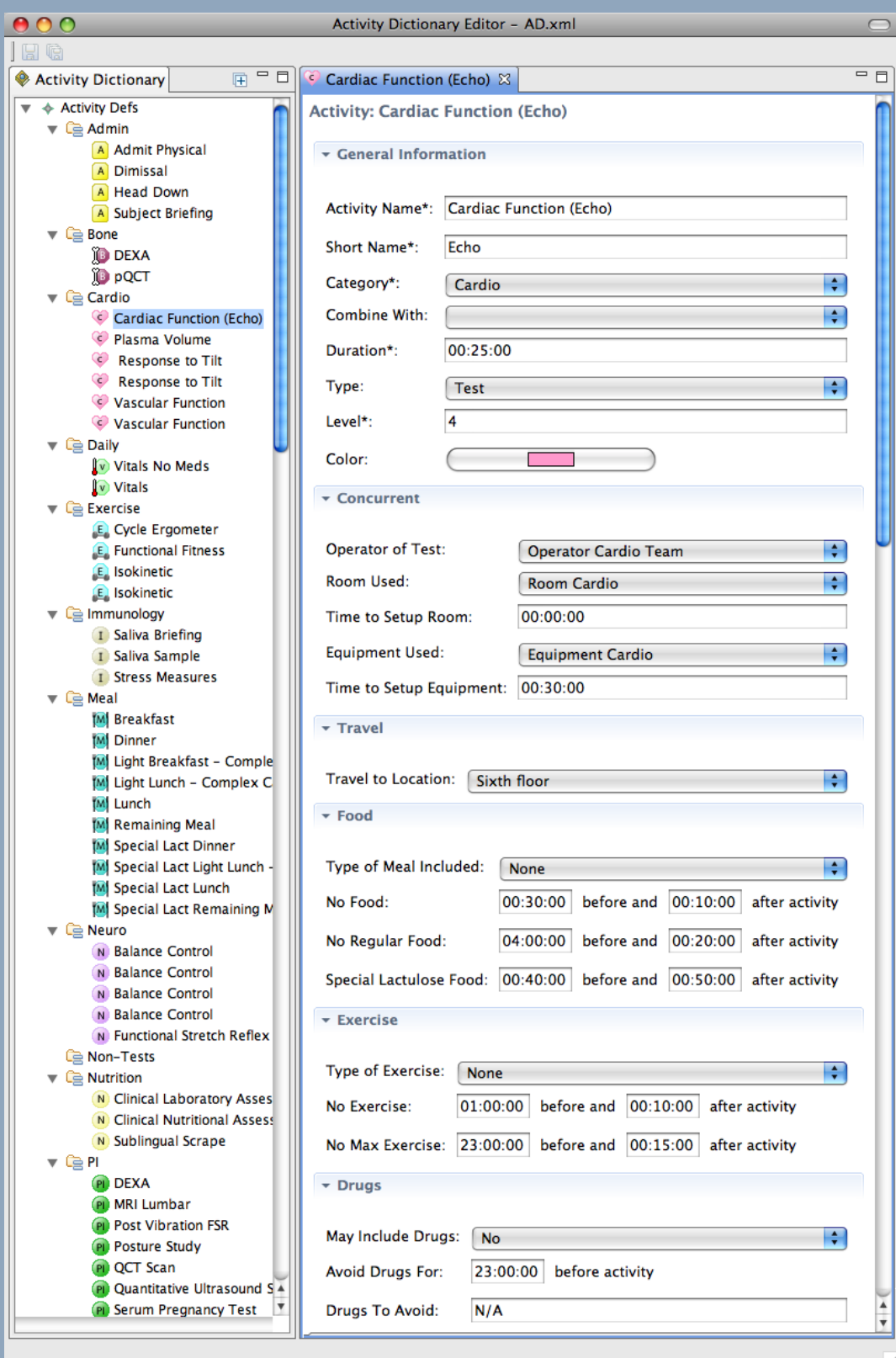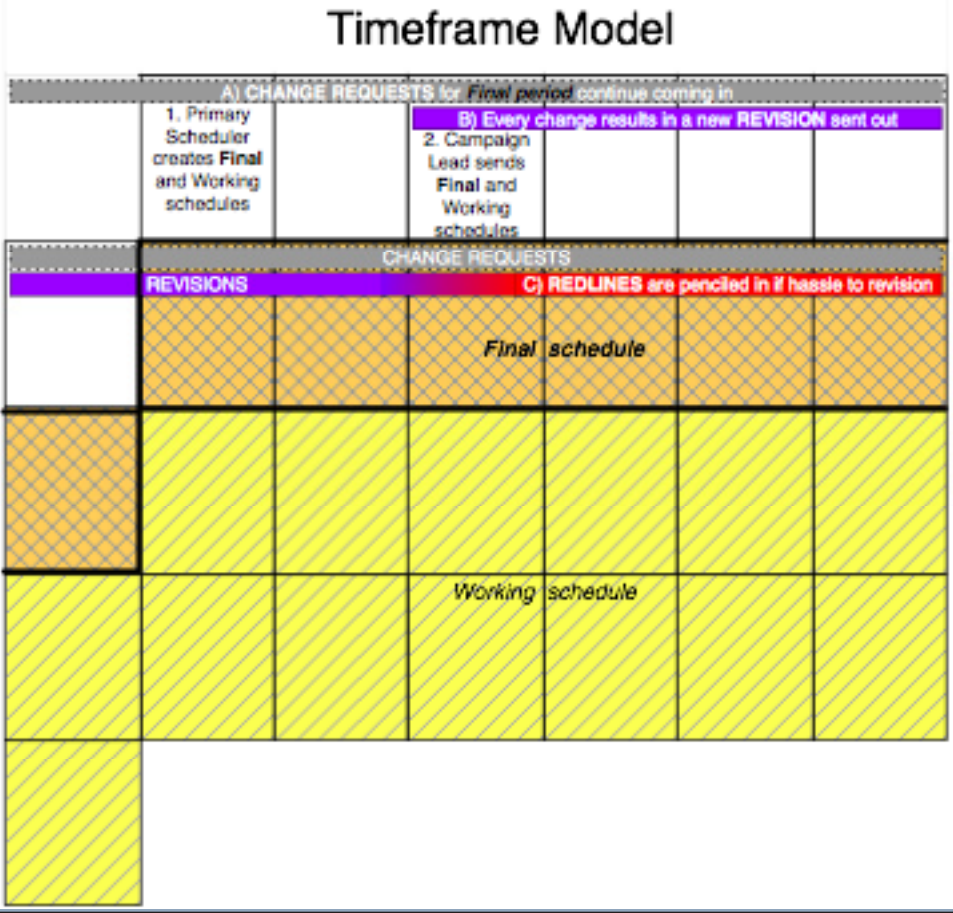

Timeline

Merge Editor

Refinement and Iteration

Unlike the Mars robotic domain where activities are determined months before the mission, the Bed Rest project had a need to **add or change activities in the middle of a campaign**. For example:
- Shortly after beginning the study, it was discovered that subjects required massage therapy every other day in order prevent their muscles from stiffening.

To facilitate the ability for the Bed Rest team to make changes to activity definitions, an **Activity Dictionary Editor** is currently under development that would allow the Bed Rest scheduler to edit attributes and constraints and almost immediately use them in SPIFe.

Activity Dictionary Editor

Soft Constraints

In the robotic domain, there exist constraints called **flight rules** that if broken can result in harm to the vehicle. Alternatively, the Bed Rest schedule had a notion of **soft constraints** where it is sometimes necessary to "bend the rules". For example:
- A lab may not wish to conduct any tests on a weekend, but if it's imperative that scientific data be collected on a Sunday the lab operators can make an exception.
- A subject should be fed lunch between 11:30 AM and 1:00 PM, but it would not be harmful to allow them to eat slightly earlier or later.

To accommodate for this in SPIFe, the ability for the user to **waive flight rules** for an activity was added, which would tell the Plan Advisor to ignore the constraints for that activity.

Plan Advisor ignoring waived activity

1 Bresina J., Jónsson A., Morris P., and Rajan K. 2005a. "Activity Planning for the Mars Exploration Rovers", *Fourteenth International Conference on Automated Planning and Scheduling*, Monterey, 2005, pp. 40-49.
2 Aghevli, A.; Bachmann, A.; Bresina, J.; Greene, K.; Kanefsky, B.; Kurien, J.; McCurdy, M.; Morris, P.; Pyrzak, G.; Ratterman, C.; Vera, A.; and Wragg, S. 2006. Planning Applications for Three Mars Missions with Ensemble. *In International Workshop on Planning and Scheduling for Space.*